Rainfall measurement comparison between two types of disdrometers

Samuel Fillon, Auguste Gires, Ioulia Tchiguirinskaia, D Schertzer, S. Lovejoy

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S. Fillon (1), A. Gires (1), I. Tchiguirinskaia (1), D. Schertzer (1), S. Lovejoy (2)

(1) U. Paris-Est, École des Ponts ParisTech, LEESU, Marne-la-Vallée, France (auguste.gires@leesu.enpc.fr), (2) McGill U., Physics dept., Montreal, PQ, Canada

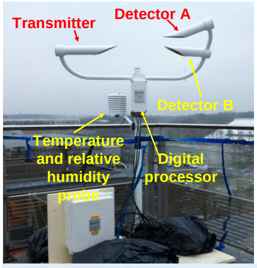
Chair "Hydrology for Resilient Cities" (sponsored by Véolia)

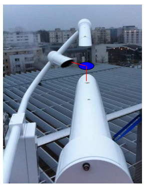
Introduction

Rainfall point measurements:
- Tipping bucket rain gauges (usually 0.2 mm tips)
-Disdrometers (binned size and velocity)

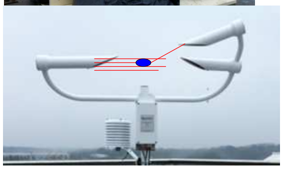
→ The quantification of the uncertainty associated with these devices is still an open question.
→ Preliminary results of a comparison campaign between two disdrometers types (Parsivel OTT and Campbell Scientific PWS100) are presented here.

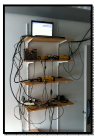
Campbell Scientific PWS100





Refraction towards the horizontal detector





Refraction towards the vertical detector

The transmitter generates four parallel laser sheets and the detectors measure the light refracted by the hydrometor (liquid drop) falling through the sampling area :
- Optical properties of refraction → the vertical detector receives signal slightly before horizontal one → estimation of the size of the drop
- 4 II sheets → periodic received signal → estimation of the velocity of the drop

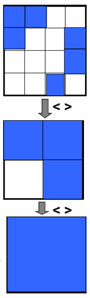
(see Ellis et al., 2006)

Multifractal analysis

Estimating statistics across scales

Definition of the fractal dimension D_F

$$\text{number of pixels with rain} = \lambda^{D_F}$$



$\Lambda = 4$: $<R_4^q>=$, $\Pr(R_4 \geq 4^{\gamma})=$

$\lambda = 2$: $<R_2^q>=$, $\Pr(R_2 \geq 2^{\gamma})=$

$\lambda = 1$: $<R_1^q>=$, $\Pr(R_1 \geq 1^{\gamma})=$

If multifractal:

$$<R_\lambda^q> \approx \lambda^{K(q)}$$

$$\Pr(R_\lambda \geq \lambda^{\gamma}) \approx \lambda^{-c(\gamma)}$$

Scaling moment function

Codimension function

$$resolution = \lambda = \frac{L}{l} = \frac{outer\_scale}{observation\_scale}$$

Quantifying the scaling variability

In the framework of universal multifractals :

$$K(q) = \begin{cases} \frac{C_1}{\alpha - 1}(q^{\alpha} - q) + Hq & \alpha \neq 1 \\ C_1 q \ln q + Hq & \alpha = 1 \end{cases} \qquad c(\gamma + H) = \begin{cases} C_1\left(\frac{\gamma}{C_1\alpha'} + \frac{1}{\alpha}\right)^{\alpha'} & \alpha \neq 1 \\ C_1 \exp\left(\frac{\gamma}{C_1} - 1\right) & \alpha = 1 \end{cases}$$

Only three parameters (based on the behavior of the average field)

- H: degree of non-conservation ($K(1)=H$)
- C_1: mean intermittency ($K'(1)=C_1+H$)
- α : multifractality index ($K''(1)=\alpha.C_1$)

Straightforward consequences on the extremes

- Large α and C_1 → strong extremes

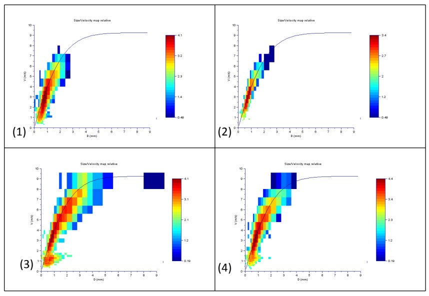
Estimation of the three exponents with the help of the double trace moment technique (DTM)

Comparison of 4 events

(1): 15th May 2013 3h15 Light rain / long duration
(2): 16th May 2013 10h18 Very light rain / Average duration
(3): 29th May 2013 21h18 Intense rain / short duration
(4): 9th June 2013 4h43 Average intensity rain / long duration

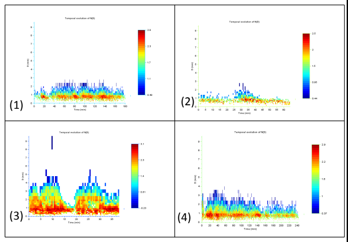
Size/Velocity maps

- Along standard $V(D)$ curves
- Heavier rainfall event → wider distribution
- For (3) and (4) a spot for small D (effect of the building?)



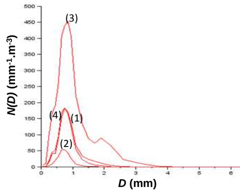
Temporal evolution of $N(D)$

$$N(D_i) = \frac{1}{S_{eff}(D_i)\Delta D_i \Delta t} \sum_j \frac{n_{i,j}}{v_j}$$

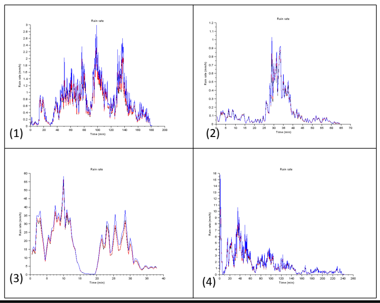


Raindrop diameter distribution

- Position of the peak similar for all curves
- Greater values for heavier event
- Wider tails for heavier event



Rain rate



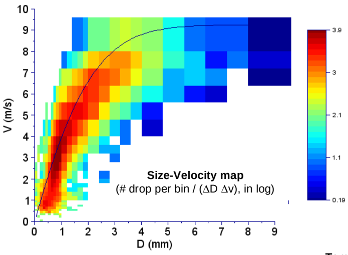
$$R = 6\pi 10^{-4} \sum_i N(D_i) v(D_i) D_i^3 dD_i$$ (Blue)

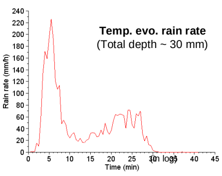
$$R = \frac{\pi}{6\Delta t} \sum_{i,j} \frac{n_{i,j} D_i^3}{S_{eff}(D_i)}$$ (Red)

R_{PWS100} (Black)

19 June 2013, 17h20-17h50, a 10 year return period event !!

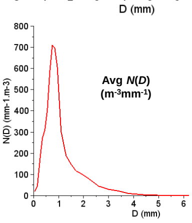
General features

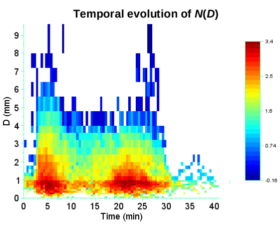




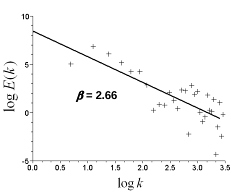
Dur. (min)	I max (mm/h)	T * (Year)
30 min	57	8.9
15 min	72	6.1
5 min	154	10.3

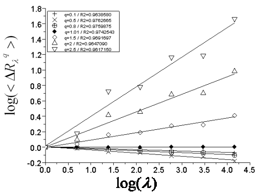
* *Estimated using a Frechet law and the data from a rain gauge located 10 km away*

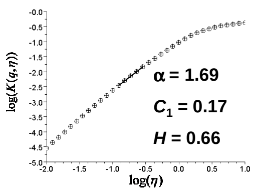




Multifractal analysis on R





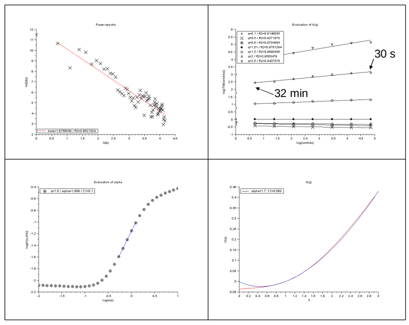


Multifractal analysis and microphysics

Multifractal analysis tools applied to rain rate (R), liquid water content (ρ_l) and number density (n).

$$n = \int_{D_{min}}^{D_{max}} N(D)dD$$

$$\rho_l = \rho_w \frac{\pi}{6} \int_{D_{min}}^{D_{max}} N(D)D^3 dD$$



Multifractal analysis on a 3 month mean for rain rate

	R	ρ_l	n
α	1,61	1,59	1,34
C_1	0,10	0,14	0,10
β	1.98	2.00	1.82
H	0.58	0.62	0.49

Conclusion

- Some standard values of α (1.6-1.7), C_1 (0.1-0.2) and H (0.5-0.6) during a rainfall event
- Multifractal tools can be used on disdrometers data to give an insight into the microphysical processes
- Only preliminary results, the two OTT parsivel still need to be installed…!

References

Ellis, R.A. et al., 2006. New laser technology to determine present weather parameters. *Measurement Science & Technology*, 17(7): 1715-1722.
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